

SPATIAL AND TEMPORAL ANALYSIS OF PRECIPITATION FOR THE STATE OF KARNATAKA, INDIA

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ABSTRACT

The present study was carried out to examine the spatial and temporal variability trends in precipitation at annual and seasonal basis for the 24 districts of Karnataka state, India. Statistical trend analysis techniques, namely the Mann-Kendall test and Theil - Sen slope estimator test were used to examine trends in both parameters at the 5% level of significance (LOS). Data analysis showed that there was notrend in all seasons as well as annual mean for precipitation and mean temperature at 5% LOS in the study area for the period during 1901-1980. But, during the last 113 years (1901-2012) increasing trend in precipitation was observed in north-eastern districts and also in Bangalore urban district of Karnataka, while decreasing trend was found in the districts under transition zone. The magnitude of increasing trend in annual precipitation varied from 90.4 to 150.3 mm in the last 113 years. Magnitude of trend variation for mean precipitation was dominant in monsoon season and for annual.

KEYWORDS: Mann-Kendall Test, Precipitation, Climate Change

INTRODUCTION

Climate change is the change in the distribution of weather patterns over periods ranging from decades to millions of years. Globally climate change has caught increasing attention in research field due to its direct and indirect impacts on all major sectors, such as hydro-meteorological, ecological, biological and socio-economic sectors. IPCC 2013 report, suggested various indicators of global climate change. For example, global mean sea level has risen by 0.19 m for the period of 1901-2010, global mean temperature (ocean and surface) has increased about 0.89°C for the period of 1901-2012, land ice is melting at the rate of 100 billion tonnes per year and arctic ice glaciers are decreasing at the rate of 11.5% per decade are some of the indicators of global climate change.

In the present study important climatic variable precipitation was considered to get the relationship between climate change and hydrology in the study area which could help in developing sustainable water resources and strategies for agricultural production. Globally, it has been estimated that, occurrence of precipitation has increased about 10 to 15 % (IPCC 2013). In Indian subcontinent precipitation trend has been random in nature i.e. both decreasing and increasing trend were reported. However total precipitation occurred over country has increased (Rupa Kumar et al. 1992; Darshana and Pandey, 2013).

Sen Roy and Belling, 2004, found that in recent years due to climate change there is increasing trend of extreme events of precipitation in the Deccan Plateau regions in the southern peninsular and North West parts of Himalayas. These changes in precipitation pattern from the mean precipitation lead to increase in hydro-meteorological extreme events such as floods and droughts over the regions.

Since the Karnataka is an agricultural-based state of India, precipitation plays an important role for fulfillment of water requirement in terms of agricultural as well as domestic purposes. Hence any change in precipitation from normal mean precipitation (at least 30 years average) will have a significant impact on socio-economic condition over the region. Furthermore, changes in precipitation pattern lead to huge impact on agriculture sector in terms of cropping pattern, reduction in production and yield. Thus, with the scenario of changing climate, the statistical analysis of precipitation over the individual places of the state becomes necessary for design of the suitable and new cropping pattern and planning & management of water resources over different parts of Karnataka. Hence a detailed study was carried out with specific objectives of spatio-temporal analysis of precipitation at the district-level.

MATERIALS & METHODS

Karnataka is located on the western coast of peninsular India, enclosed between 11.50 °N to 18.50 °N and 74 °E to 78.5 °E. Geographical area of Karnataka is about 191791 square kilometers, comprising of 30 districts “Figure 1”. Geographical zones of Karnataka are broadly categorized into three types; Coastal region, Western Ghats region and Deccan plateau (transition zone and dry zone). Based on precipitation occurred over the Karnataka state, Indian meteorological department (IMD) broadly categorized Karnataka geographical zones into three zones; coastal, north interior dry zone and south interior dry zone.

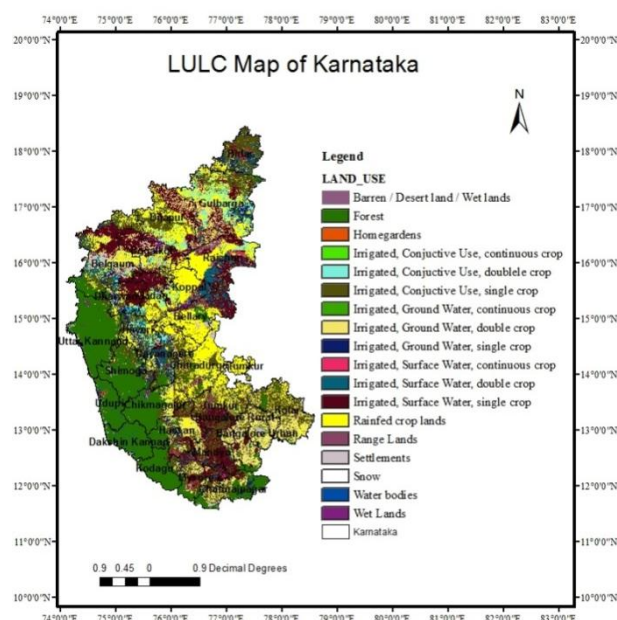


Figure 1: Geographical Map of Karnataka

Monthly precipitation of 24 districts data for the period of 113 years (1901-2012) downloaded from India water portal site (<http://www.indiawaterportal.org>). The spatial and temporal variability of precipitation are studied at annual and seasonal basis (pre-monsoon, monsoon, post-monsoon and winter) with statistical analysis. Methodology of dividing data

into seasonal basis helps in eliminating the effect of seasonality in the time series. Further, study was carried out at different time periods 1901-1940, 1941-1980, 1981-2012 and 1901-2012 for precipitation.

Trend Analysis

Trends in the hydro-meteorological data can be detected using parametric or non-parametric methods. In recent years many researchers concluded that the non-parametric methods are more suitable to trend detection in hydro-meteorological data rather than the parametric methods. Therefore in the present study a popular non- parametric method Mann-Kendall test was used to detect trend in the precipitation at 5% significance level. The Mann-Kendall test can be applied to a time series x_i ranked from $i = 1, 2, 3 \dots n-1$ and x_j ranked from $j = i + 1, 2, 3 \dots n$ such that:

$$\text{Sgn}(x_j - x_i) = \begin{cases} 1 & \text{if } (x_j - x_i) > 0 \\ 0 & \text{if } (x_j - x_i) = 0 \\ -1 & \text{if } (x_j - x_i) < 0 \end{cases} \quad (1)$$

The Kendall test statistic S can be computed as:

$$S = \sum_{k=1}^{n-1} \text{Sgn}(x_j - x_k) \quad (2)$$

In the test under the assumption of randomly ordered and independent data, statistic values of S possess normal distribution for large number of sample size. The mean and variance of statistic S are computed as:

$$E(S) = 0$$

$$\text{Var}(S) = \frac{[n(n-1)(2n+5) - \sum_{i=1}^m t_i(t_i-1)(2t_i+5)]}{18} \quad (3)$$

Where n is the sample size, t_i is the number of ties for i^{th} value and m denotes total number of tied values. The standardized Mann-Kendall test Z value for computation of statistical significance of trend in the time series is given as follow:

$$Z = \begin{cases} \frac{S-1}{\sqrt{\text{Var}(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sqrt{\text{Var}(S)}} & \text{if } S < 0 \end{cases} \quad (4)$$

The Z values of Mann-Kendall test accept the null hypothesis of no trend when $\pm Z \leq Z_{1-\alpha/2}$, where α is the level of significance at two tailed trend test. In the present study test was carried out at 5% significance level, therefore when Z value exceeds ± 1.96 null hypothesis is rejected and show the existence of trend in the series. The values of $+Z$ and $-Z$ indicates upward and downward trend respectively.

The magnitude of trend was studied by using Theil - Sen's slope estimator test. The magnitude of slope is computed as:

$$Q = \text{median} \left(\frac{X_j - X_k}{j - k} \right) \text{ for all } k < j \quad (5)$$

Where X_j and X_k are data at points j and k respectively. For the n number of data points, estimated slope is $n(n-1)/2$ and statistic value Q is the median of all estimated slope. The positive and negative values of Q indicates increasing and decreasing trend respectively.

RESULTS & DISCUSSIONS

Spatial distribution of trends in annual mean, pre-monsoon (March, April and May), monsoon (June to September), post-monsoon (October and November) and winter seasons (December, January and February) of precipitation for the 24 districts of Karnataka state are shown in Table 1. Results indicated that for the period during 1901-1980 there was no trend in all seasons as well as annual mean precipitation at 5% significance level for the whole Karnataka state. However, from the period during 1981 to 2012, both increase (5 of districts) and decrease (8 of districts) trend was observed in some districts, while no trend in precipitation was found in remaining districts (11 of districts) of the study area. Further the fluctuation of trend variation was mainly found in monsoon season and annual mean precipitation. From these results it was found that precipitation trend was shifting during the period 1981-2012 i.e. both positive and negative trends were observed.

In the last 113 years i.e. for the period of 1901-2012 the increase trend in annual precipitation was observed in Bangalore urban, Bidar, Bijapur, Gulbarga and Raichur districts at 5% significance level. Further decrease trend was found in annual mean precipitation for districts under transition zone such as Belguam, Chamarajnagar, Davangere, Dharwad, Gadag, Hassan, Haveri and Mysore districts. Seasonal analysis revealed no trend in the study area for pre-monsoon, post-monsoon and winter season except two districts (Gulbarga district for pre-monsoon and Bidar district for post-monsoon). The increase trend was observed in monsoon season at Bangalore rural and Bangalore urban districts. The magnitude of trend variation was quite similar for both annual and seasonal precipitation with respective districts in the period of 1901-1940 and 1941-1980 (Table 1). In addition, significant magnitude of trend was found in the annual mean and monsoon season of precipitation. The decreasing trend magnitude of annual precipitation was found as -0.26 to -7.87 mm/hydrologic year and -0.12 to -6.38 mm/hydrologic year for the period of 1901-1940 and 1941-1980 respectively. Further increasing trend magnitude of annual precipitation was found 0.17 to 2.19 mm/hydrologic year and 0.22 to 3.97 mm/hydrologic year for the period of 1901-1940 and 1941-1980 respectively. While for the period of 1981 to 2012 the magnitude of trend had sharply increased and decreased in the study area for the most of the districts. Maximum decrease in annual and monsoon seasonal precipitation was found at Belguam (-12.44 and -18.28 mm/year), Chamarajnagar (-17.14 and -18.57 mm/year), Davangere (-12.53 and -16.49 mm/year), Dharwad (-13.00 and -21.31 mm/year), Gadag (-8.53 and -12.64 mm/year), Hassan (-35.16 and -40.81 mm/year), Haveri (-16.01 and -22.49 mm/year), Mandya (-21.57 and -23.66 mm/year) and Mysore (-32.96 and -38.44 mm/year) districts. Maximum increase in magnitude of trend in annual and monsoon season precipitation was found at Bangalore rural, Bangalore urban, Bidar, Chickmangalore, Gulbarga, Kodagu and Raichur districts and it varied between 1.31 to 25.55 mm/hydrologic year during the period of 1981-2012.

In the long term analysis of trend i.e. for the period of 1901-2012 decrease in trend was dominant in the most of the districts (except 9 districts) in the study area. Magnitude of precipitation was not much significant in the pre-monsoon, post-monsoon and winter seasons, this was varying between 0.03 to 0.52 mm per/hydrologic year. But for the annual mean and monsoon season magnitude ranged between 1.33 to -4.85 mm/hydrologic year. The increase trend in magnitude was found in Bagalkot, Bangalore rural, Bangalore urban, Bidar, Bijapur, Gulbarga, Kolar and Raichur districts. These all districts come under high temperature zone except Bangalore rural and Bangalore urban "Figure 1". The decrease trend in magnitude was observed in the districts under transition zone such as Belguam, Chamarajnagar, Chickmangalore, Chitradurga, Davangere, Dharwad, Gadag, Hassan, Haveri, Mandya and Mysore.

CONCLUSIONS

It was found that in the last 113 years i.e. for the period of 1901-2012 the increase trend in annual precipitation was observed in Bangalore Urban, Bidar, Bijapur, Gulbarga, and Raichur districts at 5% significance level. Also, in terms of magnitude of trend, increase in annual precipitation varied from 90.4 to 150.3 mm in the last 113 years. Most of these districts are under the north eastern dry zone (high temperature zone), which are located besides the northern Andhra Pradesh. These results were conformity to the results of studies conducted by the Basista et al., 2007, and Rupa Kumar et al. 1992, which have shown the increase trend in annual precipitation over the south India (northern Andhra Pradesh). Further decrease trend in annual mean precipitation was found in the districts under transition zone such as Belgaum, Chamarajnagar, Davangere, Dharwad, Gadag, Hassan, Haveri and Mysore districts. From the period of 1901-1980 there was no trend in all seasons as well as annual mean of precipitation at 5% significance level in all 24 districts of Karnataka. But from the period of 1981 to 2012 it was found that both increase and decrease trend observed in some districts and no trend in precipitation were found in remaining districts of Karnataka state. Current results concur with the studies conducted by the Basista et al., 2007 and Darshana and Pandey, 2013, which have shown that most probable change of year was 1978 for the annual precipitation. Magnitude of precipitation was not much significant in the pre-monsoon, post-monsoon and winter season which varied between -0.03 to 0.52 mm/hydrologic year. But for the annual mean and monsoon season magnitude ranged between 1.33 to -4.85 mm/hydrologic year over the period of 1901-2012.

Due to change in precipitation pattern in Karnataka cropping pattern, agricultural production and economy of the state has been significantly affected. Water harvesting, land use planning and alternative crop choice are very effective adaptation measures to resist the heterogeneity observed in precipitation patterns among all possible strategies. Results of the proposed work will aid in designing the effective water resource planning over the Karnataka state under climate change.

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APPENDICES

Table 1: Trend Analysis of Precipitation for 40 Year Time Interval (1901-1940; 1941-1980; 1981-2012)

Name of Districts	M-K-Z-Value-1901-1940					M-K-Z-Value-1941-1980					M-K-Z-Value-1981-2012				
	AM	Pr-M	MN	Po-M	WN	AM	Pr-M	MN	Po-M	WN	AM	Pr-M	MN	Po-M	WN
Bagalkot	0.71	0.45	0.01	0.38	-0.13	0.94	0.45	1.48	0.78	0.01	-2.03	0.18	-2.84	-0.21	-0.89
Bangalore Rural	-0.10	1.20	-0.90	-0.24	0.59	0.85	0.15	1.25	0.31	-0.08	0.79	0.92	0.21	0.99	-0.41
Bangalore	-0.22	1.27	-1.04	-0.17	0.10	0.50	0.00	0.76	0.50	-0.24	2.25	2.19	0.96	1.86	-0.60
Belgaum	-0.76	0.01	-0.38	0.80	0.29	0.41	0.36	0.00	0.31	0.38	-2.71	0.47	-3.10	0.54	-0.34
Bellary	0.13	-0.27	-0.36	0.52	-1.18	-0.06	-0.17	0.31	-0.08	-0.80	-0.86	1.57	-0.99	-0.37	-1.12
Bidar	-0.36	0.43	-1.27	0.97	-0.34	-0.06	0.59	-1.08	1.34	-0.80	0.47	0.73	0.60	-0.63	-0.44
Bijapur	0.85	0.92	0.10	0.92	-0.27	1.81	0.80	1.11	0.94	-0.24	-1.83	0.89	-1.96	-0.41	-1.17
Chamarajanagar	-1.20	0.03	-1.48	-0.13	-0.29	-0.10	-0.27	-0.34	0.17	-0.43	-2.71	-0.15	-3.49	0.47	-0.60
Chikmagalur	-0.90	-0.31	-1.18	-0.24	-0.55	-0.85	-0.38	-0.71	-0.48	-0.64	0.15	1.99	-0.79	1.51	0.47
Chitradurga	0.36	1.55	0.22	0.34	-0.55	0.59	0.50	0.36	0.01	-0.71	-0.63	1.57	-1.74	0.63	-0.55
D. Kannada	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dayanagere	0.08	0.08	-0.24	0.85	-0.64	-0.29	-0.10	0.00	-0.03	-0.80	-2.19	0.76	-2.97	0.34	-0.70
Dharwad	-0.36	-0.62	-0.15	0.99	-0.36	-0.01	-0.52	-0.15	-0.20	-0.49	-1.90	0.00	-2.68	0.44	-0.34
Gadag	-0.36	-0.15	-0.31	0.24	-0.64	-0.27	-0.69	-0.10	-0.34	-0.31	-1.77	0.92	-2.64	0.60	-1.51
Gulbarga	-0.31	0.22	-1.06	0.92	-0.15	1.20	1.64	-0.15	0.85	-0.15	0.99	1.57	0.83	-0.44	-0.15
Hassan	-0.55	0.17	-0.45	-0.52	-0.34	-0.76	-1.46	-0.59	-0.66	-0.97	-2.97	1.18	-3.26	0.92	-0.11
Haveri	-0.06	-0.41	-0.27	1.27	-0.45	0.03	-0.50	0.27	-0.34	-0.52	-2.19	0.34	-3.00	0.02	-0.89
Kodagu	-0.59	-0.52	-0.66	-0.48	0.13	-0.31	-0.50	-0.48	-0.34	-1.57	2.94	1.99	2.48	2.42	-0.21
Kolar	0.71	1.92	-0.38	0.03	0.17	1.71	-0.10	2.16	0.83	-0.17	-0.47	1.51	-1.18	-0.18	0.54
Koppal	-0.50	-0.64	-0.57	0.31	-0.76	0.06	-0.38	0.34	-0.10	-0.43	-0.89	0.76	-1.38	-0.47	-1.30
Mandya	-0.36	0.45	-0.43	-0.15	0.41	-0.85	-1.01	-0.69	-0.31	-0.52	-2.71	-0.24	-3.26	1.15	-0.57
Mysore	-0.50	-0.15	-0.71	-0.13	0.36	-0.22	-1.20	-0.31	-0.34	-0.83	-2.87	-0.73	-3.32	0.15	-1.41
Raichur	-0.36	-0.66	-0.59	0.69	-0.83	0.50	1.01	0.55	-0.24	0.38	0.28	0.44	0.70	-0.79	-1.07
Shimoga	-0.71	-0.76	-0.99	0.99	-0.55	-0.92	-0.29	-0.87	-0.13	-0.50	0.05	1.09	-0.28	1.02	0.31
Tumkur	-0.08	1.34	-0.36	-0.59	0.15	0.24	0.15	0.34	-0.10	-0.22	-1.02	2.38	-2.35	0.86	-0.47
U. Kannada	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Udupi	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Note: - $1.96 < Z < 1.96$ = No trend, $Z > 1.96$ = Increase in trend, $Z < -1.96$ = Decrease in trend Pr-M- Pre-monsoon, MN- Monsoon, Po-M- Post-monsoon, WN- Winter, AM- Annual mean; NA- Not analysed